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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM

OF THE

LOS ANGELES MEETING
AT THE UNIVERSITY OF CALIFORNIA

AT

LOS ANGELES

CALIFORNIA

JUNE 26–29, 1935

IN AFFILIATION WITH THE PACIFIC DIVISION OF

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

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The American Physical Society

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AMERICAN PHYSICAL SOCIETY

LOS ANGELES MEETING, JUNE 26–29, 1935

IN AFFILIATION WITH

THE PACIFIC DIVISION OF THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE 200th regular meeting of the American Physical Society in affiliation with the Pacific Division of the American Association for the Advancement of Science will be held in Los Angeles, California in the Auditorium of the Physics-Biology Building of the University of California at Los Angeles, beginning on Wednesday morning, June 26, and extending to Saturday noon, June 29, 1935.

The morning sessions of the symposia on Wednesday and Thursday will begin at 9:30 and the afternoon sessions will begin at 1:30 o'clock. The programs of the ten-minute papers will begin at 9 o'clock in the morning and at 1:30 in the afternoon. The sessions will be extended to Saturday afternoon if the number of papers on the supplementary program warrants.

JOINT SESSION WITH THE ASTRONOMICAL SOCIETY OF THE PACIFIC

The program will be as follows: On Wednesday there will be a joint session with the Astronomical Society of the Pacific consisting of six invited papers.

SYMPOSIUM ON NUCLEAR STRUCTURE

On Thursday there will be a symposium on nuclear structure and disintegration. There will be five invited papers beginning with a general summary of nuclear structure and covering the recent advances in this field on the Pacific Coast. Subsequent to this the Session will be addressed by Professor R. W. Wood, Johns Hopkins University, President of the American Physical Society, on a topic of his own choosing.

REGULAR SESSIONS

On Friday and on Saturday morning there will be the regular sessions for the presentation of ten-minute papers. The Society will meet at luncheon at Kerckhoff Hall in the Students' Union Building, if possible, at noon on Wednesday, Thursday and Friday. The luncheon on Thursday will be the official luncheon of the Physical Society, with President Wood presiding. Owing to the geographical distribution of residences and hotels in Los Angeles, no attempt will be made to bring the members together for the customary formal dinner in the evening.

Hotels, Dormitories and Auto Camps. *Hotel Christie*, 6724 Hollywood Boulevard, rooms with bath, $2.50 and up; without bath $1.50 and up.

Hotel Clark, 426 South Hill Street, with bath $2.00 and up.

Hollywood Plaza Hotel, 1637 North Vine Street, single with bath, $2.50 and up; double with bath, $3.00 and up.

Pacific Palisades Auto Camp, Roosevelt Highway above Santa Monica.

Lincoln Auto Court, Santa Monica, Lincoln Boulevard and Marine Street, cottages $1.25.

The Brockton Cottages, Santa Monica, 1225 Brockton Avenue, cottages from $1.50 to $3.50.

Additional information will be available at the registration desk.

Lodging and Meals on or near Campus. Four different dormitories offer rooms for about $1.00 per day (meals not being in all cases available); Mira Hershey Hall, Bannister Hall, Douglass Hall, Holmby Hall. Also, a number of fraternity and sorority houses will be available, at about the same rate for lodging, with meals available at some of the houses.

Meals. Kerckhoff Hall, Students' Union Building on the campus, furnishes lunch at noon and coffee-room service until 5 P.M. and arrangements for group luncheons and dinners may be made. Other cafes in the Village, ½ mile from campus.

Excursions

Excursion A—Mt. Wilson Observatory

A trip to the Mount Wilson Observatory is planned for Friday evening, June 28. Special busses will leave U.C.L.A. campus at 4 P.M. An illustrated lecture on the work of the Observatory will be given by a member of the Observatory staff at the Hotel at 7:30. After the lecture, if the sky is clear, an opportunity will be given to look at Jupiter and other heavenly bodies through the 60-inch telescope. The 100-inch telescope will also be shown. At 10:15 the special busses will leave. Visitors may prefer to spend the night at the Hotel and take the regular bus down at 8:00 on Saturday morning.

Excursion E—The California Institute of Technology

A half-day trip to the California Institute of Technology in Pasadena (23 miles distant) to visit the Physical, Chemical and Biological Laboratories, the Aerodynamics Laboratory, the High Tension Laboratory and the Optical and Astrophysical Shops designed to assist in the construction of the 200-inch telescope and subsidiary instruments.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.) Papers received after the program has been printed will be placed in the supplementary program.

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

The supplementary papers may be called for at the end of any regular session.

Titles and abstracts of the papers to be presented before the Society are given in the following pages. These abstracts have not been corrected by the authors. After correction they will be published in an early issue of the *Physical Review*. Authors should send corrections to the Editorial Secretary, American Institute of Physics Incorporated, 11 East 38th Street, New York, New York.

Other meetings for the current season are as follows:

201. November 29–30, 1935, Baltimore, Maryland.
202. December, 1935, Berkeley, California.
203. December, 1935, Annual Meeting, St. Louis, Missouri.

Leonard B. Loeb
Local Secretary for the Pacific Coast,
University of California, Berkeley, California
June 10, 1935.

PROGRAM

Joint meeting with the Astronomical Society of the Pacific

Symposium on the Geologic and Cosmic Age Scales

WEDNESDAY, JUNE 26TH AT 9:30 A.M., ROOM 19, CHEMISTRY BUILDING

1. **The Age of the Earth from Sedimentation.** GEORGE D. LOUDERBACK, *University of California, Berkeley.*
2. **The Age of the Earth from Radioactive Disintegration Products.** ROBLEY D. EVANS, *Massachusetts Institute of Technology.*
3. **The Age of the Earth from the Changes in its Temperature and Elastic Properties.** BENO GUTENBERG, *California Institute of Technology.*
4. **The Age of the Galaxy from the Disintegration of Galactic Star Clusters and Binary Star Systems.** G. P. KUIPER, *Lick Observatory.*
5. **The Age of the Universe from the Red Shift in the Spectra of Extragalactic Objects.** RICHARD C. TOLMAN, *California Institute of Technology.*
6. **On Attempts to Reconcile the Long and the Short Time Scales in Cosmogony.** PAUL S. EPSTEIN, *California Institute of Technology.*

A discussion will follow these lectures. Mimeographed abstracts of the addresses may be obtained at the office of the Department of Astronomy, Room 343, Chemistry Building. If necessary, this symposium will be continued in the afternoon session.

WEDNESDAY, JUNE 26TH AT 1:30 P.M., ROOM 19, CHEMISTRY BUILDING

Continuation from the morning session of the symposium,

The Geologic and Cosmic Age Scales

Symposium on Nuclear Structure. Two sessions

THURSDAY, JUNE 27TH AT 10:00 A.M., AUDITORIUM OF THE PHYSICS DEPARTMENT

1. **A Survey of Present Knowledge of the Nucleus.** CARL D. ANDERSON, *California Institute of Technology.*
2. **Recent Developments in Artificial Transmutation.** ERNEST O. LAWRENCE, *University of California.*
3. **Gamma Rays from Nuclear Transmutations.** H. RICHARD CRANE, *California Institute of Technology.*

THURSDAY, JUNE 27TH AT 2:00 P.M., AUDITORIUM OF THE PHYSICS DEPARTMENT

4. **Advances in the Mathematical Physical Interpretation of the Nucleus.** WILLIAM V. HOUSTON, *California Institute of Technology.*
5. **Absorption of High Energy Electrons.** SETH H. NEDDERMEYER, *California Institute of Technology.*
6. **Eccentricities of High Explosives.** ROBERT W. WOOD, *Johns Hopkins*, President of the American Physical Society.

PROGRAM

FRIDAY MORNING AT 9 O'CLOCK

Physics Department Auditorium, Physics-Biology Building

1. Structure of a Heavy Deposit of Solid Selenium Condensed from the Vapor, the Liquid being at about 250°C. L. E. DODD, *University of California at Los Angeles.*—A condensation surface was provided by the hemispherical end of a glass tube kept cool by a steady flow of tap water through it. At a good vacuum in the outer tube, the vapor was fed to this cold surface through a platinum barrier pierced with apertures, the liquid being maintained at a temperature (about 250°C) well above the melting point, so that the condensation was relatively rapid. The resulting deposit showed some striking structural features, described in this paper with photographs and photomicrographs. The nature of the deposit in general is microcrystalline, with a grosser structure of what appear to be crystal units. In this deposit has been found the nuclear "amorphous" layer corresponding to that found by Goetz[1] with bismuth deposited under somewhat similar conditions.

[1] Goetz, Nature **132**, 206 (1933).

2. A.C. Voltage Stabilizer Unit. H. J. WHITE AND M. E. GARDNER, *University of California.*—An iron core choke coil provided with an auxiliary winding for direct current can have its impedance changed by changing the direct current in the auxiliary winding. When a current is passed through the d.c. coil the flux magnetizes the iron and makes it less receptive for additional magnetic flux from the a.c. coils and hence the impedance is lowered. Thus the potential drop across the choke coil can be regulated by varying the magnitude of the current in the auxiliary winding. Such a device can therefore be employed to control the a.c. voltage applied to a load. This regulation can be made automatic by applying the load voltage to a rectifier and filter unit and balancing this against the potential from a battery. The resultant potential differences are amplified and applied to the grid of a small power tube. The plate current of this tube is used as the control current in the auxiliary winding of the choke coil. Any change in the applied voltage will thus be almost completely absorbed in the choke coil. The choke coil may be designed to carry very large load currents and the voltage drop across the coil can be made sufficiently large to compensate for line voltage fluctuations of considerable magnitude. An experimental model of the stabilizer, controlling about 10 amperes at 100 volts, maintained the load voltage constant to within 0.2 volt for a line voltage change of 20 volts.

3. Acoustical Absorption as a Function of Frequency and Angle of Incidence. F. A. OSBORN AND PAUL M. HIGGS, *University of Washington.*—A parallel beam of sound produced by a loudspeaker at the principal focus of a parabolic mirror of five feet aperture is directed against a plane surface of the material under investigation. The regularly reflected sound beam is received by a second parabolic mirror and focused upon a condenser microphone. The interference pattern formed at the focus of the receiving mirror is kept in motion by frequency-modulating the sound. The absorption coefficient of the material is given by: $a=1-(A/B)^2$, where A is proportional to the sound pressure indicated by the microphone when receiving the beam reflected from the material and B is proportional to the pressure indicated when the mirrors are placed coaxially and facing one another. The total length of air path traversed by the sound is the same for all measurements. Coefficients of three typical commercial materials have been determined for frequencies from 500 to 4000 cycles per second and at angles of incidence between fifteen and seventy degrees. The results obtained are in agreement with the known acoustical properties of the materials. This work is preliminary to further investigation of acoustical absorptions.

4. Polarization Bands. JOHN STRONG, *California Institute of Technology.*—I have used the name, polarization bands, to refer to the band phenomenon discovered by R. W. Wood[1] because the bands occur only for the polarization perpendicular to the grating ruling. The second conspicuous property of these bands is the fact that their position, λ, depends on the angle of incidence, i, of the light on the grating. Measurements of polarization bands have been made with the grating, exhibited at the Pacific Coast meeting last June, coated with water, gold, copper, silver, magnesium and aluminum. This grating is ruled on an aluminum film supported by a plate glass foundation. The grooves are 0.2μ wide and 1.67μ apart. The grating gives double bands, a bright band in juxtaposition to, and on the red side of, a dark band. The dark band exhibits a sharp edge on its blue side. No change in the position of the sharp edge of the dark band was observed for any of these coats. However, the different metals were observed to shift the bright band. This shift is measured by Δ in the equation $(n-\Delta)\lambda=1\pm\sin i$, where n is an integer. For any particular metal, silver for example, Δ is a function of λ only. Values of Δ for silver vary from 0.1 at $\lambda=6800$A to 0.54 at $\lambda=4500$A. Δ's corresponding to the sharp edge of the dark bands are zero, for all metals as well as for water, at all wavelengths observed. This phenomenon of the bands seems to be a general property of the diffraction grating. It is desirable to have a physical picture of its origin.

[1] R. W. Wood, Phil. Mag. **4**, 396 (1902).

5. Two Radioactivities Produced in Magnesium by Deuteron Bombardment and Their Excitation Functions. M. C. HENDERSON, *University of California.*—Under bom-

bardment by 3.3 MEV deuterons, magnesium becomes radioactive with the emission of negative electrons and with two decay periods: $10\frac{1}{4}\pm\frac{1}{4}$ min. and 15 ± 1 hr. These periods are characteristic of Mg^{27} (Fermi) and Na^{24} (Lawrence). The reactions presumably are:

$$_{12}Mg^{26}+{}_1H^2={}_{12}Mg^{27}+{}_1H^1; \quad {}_{12}Mg^{27}={}_{13}Al^{27}+\text{beta}$$
$$_{12}Mg^{26}+{}_1H^2={}_{11}Na^{24}+{}_2He^4; \quad {}_{11}Na^{24}={}_{12}Mg^{24}+\text{beta}.$$

The alpha particles and protons have not been looked for. The Mg^{27} beta rays have 2.0 MEV maximum energy, determined by absorption in Al, and there is possibly a soft gamma ray. The voltage excitation functions of these two activities have been studied by exposing a pile of thin magnesium foils (0.0024 cm or 1.5 cm air equivalent) to the deuteron beam and measuring the activities of the foils separately. After a two-hour exposure to about 0.4 microampere, the initial activities of the top foil were 19.5 for Mg^{27} and 0.18 for Na^{24}. The fifth foil, at 2.0 MEV deuterons, gave similarly 2.36 and 0.007. No Na^{24} could be detected at less energy. At 3.3 MEV one atom becomes Na^{24} for each ten Mg^{27}. Both activities increase nearly exponentially with voltage at low voltages but at 3 MEV show signs of reaching a maximum. The Na^{24} excitation function is a steeper function of the voltage than Mg^{27}. An excitation curve of the Gamow type fits Na^{24} and it is hoped to fit one of the new Oppenheimer type[1] to Mg^{27}. The thick target yield of Mg^{27} atoms is about 5 per ten million 3.3 MEV deuterons. The nuclear cross section (Mg^{26}) for transmutation at 3.3 MEV is about 1.4×10^{-26} cm^2.

[1] Science **81**, 421 (1935).

6. The Spectrum of Ce IV. R. J. Lang, *University of Alberta.*—The spectrum of cerium has been photographed by means of a two-meter vacuum spectrograph and a vacuum spark source from 3200A to 250A. An analysis of the Ce IV spectrum has resulted in the location of the following multiplets: $6S-6P$, $6P-6D$, $6P-7S$, $5D-6P$ and $5D-5F$. Previous work by Badami on this spectrum is not correct.

7. Photo-Ionization in Gases. R. N. Varney and L. B. Loeb, *University of California.*—The balanced space-charge, positive ion detector, used in the experiments on ionization by positive alkali ions[1] has been used in the study of photo-ionization in gases. The following experiments were performed: (1) A hydrogen discharge tube, operated by either a 1000 or an 8000 volt transformer, was set up so that the radiation emitted could pass through a fluorite window into one of the space-charge, ion detectors. The detector contained N_2 at 0.02 mm pressure. When the pressure in the discharge tube was lowered to about 5 mm or less, the character of the discharge changed noticeably and ionization of the N_2 was observed, but it was definitely shown that all ionization that occurred was of electrostatic origin, despite careful shielding, and was not caused by radiation. It is believed that this may explain to some extent the ionization of gases observed by Lenard,[2] for he used an intense, high-frequency aluminum spark as a light source. (2) An apparatus similar to that used by Mohler[3] was used in which electrons of energies up to 150 volts were allowed to ionize the gas at one end of a tube and the resulting radiation to ionize the same gas in one of the balanced space-charge cylinders at the other end. As observed by Mohler, photo-ionization of argon by its own radiation was found, but this disappeared when a fluorite window was inserted. The same was true in xenon gas. Since xenon has a metastable level near 1500A, this experiment seems to eliminate the possibility of ionization being produced by absorption of two quanta, each having a fraction of the necessary energy. No ionization of N_2 by its own radiation was observed with or without fluorite window. This is analogous to Mohler's non-observance of ionization in H_2. Similar results were observed in air.

[1] Varney, Phys. Rev. **47**, 483 (1935).
[2] Lenard, Heidelberg. Akad. der Wiss. 1910–1911.
[3] Mohler, Phys. Rev. **28**, 46 (1926).

8. Field Current Emission at Small Currents. F. R. Abbott and Joseph E. Henderson, *University of Washington.*—Field emission from a carefully shielded tungsten filament surrounded by coaxial copper electrodes was investigated over a wide range of applied potential. Currents down to the order of 10^{-17} amperes were measured by use of an FP54 Pliotron used in a balanced circuit with floating grid. The higher range of currents to 10^{-4} amperes were measured directly by a galvanometer. The pressure was maintained at about 10^{-8} mm Hg. The linear relation between the logarithm of the current and the reciprocal of field intensity, as given by the equation, $i=Ce^{-b/F}$, clearly exists throughout the entire range investigated. Previous tests with poorer vacuum conditions (10^{-7} mm Hg) had indicated a slight deviation from this linear relation. A preliminary investigation of the energy distribution of the emitted electrons has been made for a total current of about 10^{-14} amperes. The main features of the observed distribution for higher currents[1] were observed also throughout the lower range of currents.

[1] Henderson, Abbott, Dahlstrom, Phys. Rev. **41**, 261 (1932).

9. The Velocity of Sound in Free Air in the Frequency Range 3.5 to 15 K.C. as a Function of Humidity. Leo P. Delsasso and John H. Munier, *University of California at Los Angeles.*—The experimental arrangement, previously reported to the Physical Society at the Los Angeles meeting in December, for accurately determining the velocity of sound in air has been used in a constant-temperature, acoustically treated room for the purpose of verifying experimentally the anomalous dispersion of sound predicted by the theory of H. O. Kneser and others.

10. The Scattering of High Energy Protons by Oxygen Nuclei. Milton G. White, *University of California.*—In view of the apparently anomalous scattering of high energy protons by hydrogen it is of some interest to examine the scattering by heavier nuclei. During the course of some cloud chamber experiments on the scattering of protons by hydrogen a number of impacts with oxygen were observed, the oxygen being supplied by the water vapor in the cloud chamber. Some 1045 stereoscopic photographs were examined in which about 28,000 protons of energy greater

than 800 kv entered the chamber. Of these protons about 15 percent had an energy greater than 1000 kv. A total of 97 measurable collisions with oxygen were observed. Although such meager data can not be regarded as conclusive the results do strongly suggest that Rutherford scattering is entirely adequate to explain the results. It was found that the scattering decreased rapidly with increasing angle of scattering and increasing energy of the incident proton. With the energies here available one would hardly expect to find any serious deviation from Coulomb's Law. However, since several thousand more photographs will soon be available it will be possible to give a definite answer to this problem sometime in the near future.

11. Absorption of Cosmic Radiation in Matter. A. W. NYE, *University of California; University of Southern California.*—Absorption of cosmic radiation, near sea level, was measured for water, sand, coal, copper sulphate, iron sulphide and barium sulphate, with triple coincidence Geiger counters. The materials were contained in a hopper and the counters arranged in vertical alignment underneath. The hopper was open to the sky in the cases of water and sand, and covered with a light wood roof in the others. Runs were made for various absorbing thicknesses up to 101.5 cm. Absorption coefficients were found to be nearly linear with density; the absorption per bound electron was nearly constant, decreasing somewhat for FeS and $BaSO_4$. Correspondence with Bloch's equation was very good, indicating that the absorption was largely a bound electron phenomenon with deep-lying electrons less effective. Shower effects were measured with the top tube out of line by varying amounts. The showers in some cases reached a maximum with increasing thickness of absorber and in others no maximum was reached, indicating greater penetration of shower producing radiation than usual. Tubes disposed in other geometrical modes gave evidence of the amount of the spread of the showers.

12. The Raman Spectrum of Heavy Benzene. R. W. WOOD, *Johns Hopkins University.*

FRIDAY AFTERNOON AT 1:30 O'CLOCK

Physics Department Auditorium, Physics-Biology Building

13. Further Study of the Vegard-Kaplan Bands. JOSEPH KAPLAN, *University of California at Los Angeles.*—By using the same tube in which the Vegard-Kaplan bands of N_2 were discovered by the author, but by greatly diminishing the current and interrupting the discharge so rapidly that it did not have time enough to come to a steady state, it has been possible to enhance greatly these bands relative to the strong second-positive bands and the Goldstein-Kaplan bands. This has made it possible to photograph several new members of this system and it makes highly probable the discovery of more new bands of this system when longer exposures are used. In spite of the large reduction of current in the tube the absolute intensity of the Vegard-Kaplan bands has not gone down correspondingly. Since these bands originate on the metastable $A^3\Sigma$ state of N_2 it is thought that this technique of excitation can be extended to the photography of radiation from other metastable atomic and molecular states.

14. The Variation of Sparking Potential with Intense Ultraviolet Illumination. HARRY J. WHITE, *University of California.*—The static sparking potential has been found to be lowered by illuminating the cathode of a spark gap with intense ultraviolet light, an auxiliary spark gap being used as the source of ultraviolet illumination. The photoelectric current released from the cathode of the illuminated gap was about 10^6 times larger with this source than with a quartz mercury arc for illumination. The amount of lowering of the sparking potential was found to increase as the intensity of the spark illumination was increased and reductions up to about 10 percent were noted in air. The reduced sparking potentials in air were found to be a function of gas pressure times gap length and therefore obey Paschen's law. The approximate law for the amount of lowering of the sparking potential can be expressed by the condition that a certain number remains constant. This number is the number of positive ions generated by electron collision in the gas as the result of a given number of photoelectrons being liberated at the cathode by one flash of the illuminating spark. One may interpret this as meaning that the breakdown is a space-charge phenomenon and that some fixed value of the field is necessary for breakdown to occur. Then if the distribution of the space charge does not change appreciably, the amount necessary to produce the given field will be constant.

15. The Radioactivity of Oxygen, Silicon and Phosphorus under Deuteron Bombardment. HENRY W. NEWSON, *University of California.*—It has been found that oxygen, silicon and phosphorus become radioactive after bombardment with 2.8 MV deuterons. The half lives are 1.16 minutes, 160 minutes and 14.5 days, respectively. All of these periods are identical with those of known radioactive substances which are probably formed in these new reactions:

$$O^{16} + D^2 \rightarrow F^{17} + n^1$$
$$Si^{30} + D^2 \rightarrow Si^{31} + H^1$$
$$P^{31} + D^2 \rightarrow P^{32} + H^1.$$

Chemical analysis confirms the last two reactions. The excitation function of the oxygen activity has been measured by allowing the beam to pass through a series of cop-

per screens in an atmosphere of oxygen. The activities which are deposited on the screens by recoil, plotted against the residual ranges of the deuterons, give a fair approximation of the excitation curve. The activation shows a threshold at 1.7 MV; this is probably due to the loss of that amount of energy in the reaction. The absorption of the electrons from Si^{31} and P^{32} has been measured in aluminum. The maximum range for silicon is 0.616 gram per square centimeter, while that for phosphorus is 0.712; the corresponding energies, calculated from the empirical rule of Feather, are 1.38 and 1.57 MV, respectively. F^{17} emits positrons.

16. The Photoelectric Effect of Aluminum Films Deposited by the Vacuum Evaporating Process. E. GAVIOLA AND JOHN STRONG.—The effect has been studied using a carefully cleaned and partially outgassed glass cell provided with a quartz window and a charcoal-liquid air trap. The cell has the shape of a horn, so that absorption of the oncoming radiation is practically total. As light source a mercury lamp was used. The light was resolved by a Hilger quartz monochromator. We have found that the long wavelength limit of the sensitivity curve lies between 2800 and 2900A, and that it has a definite selective maximum around 2700A.

17. The Existence of Townsend's Coefficient β in Gaseous Breakdown at Higher Pressures. D. Q. POSIN, *University of California.*—If a sufficiently low pressure is chosen, the simple Townsend equation for electron current delivered to an anode as a function of plate separation (and constant *average field*) holds extremely well for N_2 throughout the range of investigation between X/p 20 and 215 (X in volts per cm and p in mm in Hg). If the pressure is high enough, the curves corresponding to X/p between 120 and 215 can all be *made* to deviate from the simple Townsend requirement; i.e., at some plate distance (the apparatus permits investigation between 1 and 7.5 cm) the current begins to rise sharply. This sharp increase has been attributed to date to the Townsend β or γ coefficients—i.e., (β) to gaseous ionization by positive ions or (γ) electron liberation from cathode either by positive ion bombardment or photoelectric liberation due to excitation radiation from the gas. A study at $X/p=120$ made for the pressures below gave a deviation from the normal curve at the distances noted.

p (mm)	d_t (APPARENT TURNING POINT IN CM)	APPROX. PRODUCT $p \times d_t$
1.4	4.2	5.88
1.33	4.4	5.85
1.015	5.4	5.48
0.93	5.7	5.3
0.735	7	5.15

In each case the value of α/p (α as taken from the "normal" part of the curve) is approximately 0.95, *a constant.* Calculations of β/p from the curves show that not only does β/p vary irregularly from curve to curve (all $X/p=120$) but it is not even constant for a given curve. Moreover, for a given X and p the rate of abnormal increase beyond the turning point is a function of the initial electron current density (liberated from the cathode by the external ultraviolet source). Calculation shows that the so-called "β" is a function of current density at a given X and p. Thus in N_2 and also probably in air[1] Townsend's original interpretation of the phenomenon in terms of a β is not tenable in this pressure range. The abnormal current increase appears to be due to a constantly increasing variable, α, resulting from a non-uniform field between the plates. Accordingly at sufficiently high X and p or large d, the positive ions build up a sufficiently large space charge to distort the field between the plates, giving α on the average higher values than expected from the field $X=V/D$ applied. Hence in the high pressure range, the static spark is preceded by enormous field distortion due to positive ion space charge as the result of which ultimately processes occur at the cathode which lead to the breakdown.

[1] M. Paavola, Arch. f. Elektrotech. **22**, 443 (1929); F. H. Sanders, Phys. Rev. **44**, 1020 (1933).

18. Search for Interaction of Matter and Radiation as Explanation of Nebular Red-Shift. R. J. KENNEDY AND WALTER H. BARKAS, *University of Washington.*—The possibility of an effect of the free electrons in a highly ionized gas on the frequency of light traversing it has been investigated. Ions to a density exceeding 10^{12}/cc can be produced in a low voltage arc. The line Hg 5461A was caused to traverse the discharge of a battery of low voltage arcs in helium. By means of a fixed quartz interferometer in vacuo a frequency shift of about 1 part in 10^{10} could have been detected. Approximately two hundred photographs of the rings were taken. Alternate exposures were "controls." A very satisfactory null result was obtained. The sensitivity was such as to eliminate any probability that the observed red-shift of extra galactic nebulae has its origin in an interaction of the light and the thinly diffused, ionized, gaseous substratum of the Universe.

19. The Vapor Pressure of Hydrogen Deuteride. R. B. SCOTT AND F. G. BRICKWEDDE, *National Bureau of Standards.*—Hydrogen deuteride (HD) was separated by distillation from 4 liters of an equilibrium mixture of H_2, HD and D_2, containing equal parts of hydrogen and deuterium, by use of a still with a reflux rectification column, immersed in liquid hydrogen. There were obtained 500 cm³ of HD of purity 99.95 percent or better as estimated by a comparison of its vapor pressure with that of two fractions collected immediately before and after. The vapor pressure of this "pure" HD was compared with that of liquid normal H_2 in the range 13.92 to 20.38° K. The following empirical equations were obtained, expressing pressures in mm of Hg:

$$\log_{10} P(\text{HD liquid}) = -0.85411 + 1.27713 \log_{10} P(H_2) - 0.02212 \log^2_{10} P(H_2)$$

$$\log_{10} P(\text{HD solid}) = -1.11571 + 1.33969 \log_{10} P(H_2)$$

TEMPERATURE, °K	VAPOR PRESSURE IN MM OF HG		LATENT HEAT OF HD IN CAL/MOL	
	H_2	HD	VAPORIZATION	FUSION
22.13[1]	1230	760.0		
20.38	760.0	438.0	261	
16.60[2]	201.4	93.6	265 (liquid)	37
16.60	201.4	93.6	302 (solid)	
13.92	54.0	15.96	296	

[1] Obtained by extrapolating the vapor pressure equation to $P(\text{HD}) = 760$ mm.
[2] Triple Point.

By use of the Clapeyron equation and the equation of state of H_2 for HD, latent heats were calculated from the above equations for HD and the vapor pressure-temperature equation of normal hydrogen.

After 15 days there was no reversion to the equilibrium mixture of H_2, HD and D_2 that could be detected by a change in vapor pressure.

20. Short-Lived β-Radioactivity. H. R. CRANE, L. A. DELSASSO, W. A. FOWLER AND C. C. LAURITSEN, *California Institute of Technology.*—Cloud chamber investigations have been made of the half-lives and energy spectra of the short-lived β-active isotopes produced by bombarding various targets with deuterons. The disintegrations producing the radio elements are believed to be accompanied by proton emission. The results are tabulated below:

TARGET	ACTIVE ISOTOPE	E_{max}	HALF-LIFE
Boron	B^{12}	11.0 mev.	0.02 ± 0.01 sec.
Lithium	Li^8	9.5 mev.	0.5 ± 0.1 sec.
Carbon	No activity		
Fluorine	F^{20}	4.5	

The accuracy of the masses of the isotopes involved in the Boron transmutation and the great spread in the energy spectrum indicates that B^{12}, in disintegrating, loses an amount of energy corresponding to the upper limit of the electron spectrum and not to the mean energy.

21. The Energy of Formation of Negative Ions in Oxygen. LEONARD B. LOEB, *University of California.*—A year ago preliminary results were obtained on the energy required to remove an electron from the O_2 ion, using negative ions formed by a 100 kilocycle arc in O_2 and freed of electrons by a high frequency transverse field (filter) by subjecting the ions to a more uniform transverse high frequency field (smasher) whose potential could be varied until the ions gained enough energy to lose their electrons in molecular impacts. The phenomenon was detected by an abrupt decrease in the ion current *through* the smasher (accompanied by an increase in the current *to* the smasher), due to capture of the electrons liberated. The phenomena observed from 25 mm to 2 mm were studied at 10^6, 3×10^6 and 10^7 cycles per second in the smasher field. Very complex curves were encountered under the different conditions. At 3×10^6 and 10^6 cycles between 2 and 13 mm pressure a phenomenon interpreted with some certainty as due to break up of the negative ion was observed to give a linear relation between field strength and pressure. This gives the value of X/p for negative ion break up as 85 (X volts/cm p in mm of mercury). As at just this range of values of X/p the free path and thus average energy of ions in a field in a gas is uncertain, we can only assert that this corresponds to an energy *not less than 0.12 volt and not more than 0.64 volt.* The higher figure is in all probability more nearly the correct value. It is hoped that new methods under investigation may throw more light on the energy of ions in a force field.

22. The Total Energy Distribution for Field Current Electrons. R. K. DAHLSTROM, K. V. MACKENZIE AND JOSEPH E. HENDERSON, *The University of Washington.*—The total energy distributions for field current electrons have been measured by a method similar in principle to the one described previously.[1] This was done by using a tungsten point emitter placed at the center of two concentric spheres. The inner sphere was really a grid formed by drilling the sphere with a large number of holes. Field electrons emitted from the tungsten point were accelerated to the grid, and those that passed through were then decelerated by the same potential which liberated them, the outer sphere being connected through a small accelerating potential to the tungsten point. Analysis of the current to the outer sphere as a function of the small accelerating potential gave the distribution in energy of the field electrons. The distribution curves obtained earlier with coaxial cylinders gave the distribution for electrons emitted on a plane perpendicular to the axes of the cylinders, not the total energy distribution. The present method, since the point was almost completely surrounded, gave the total energy distribution. The distributions found in this manner exhibit the major characteristic obtained earlier,[1] i.e., a rapid rise to a maximum when the work done by the field was approximately 4.5 volts. The range of energies was not so great, extending over about 10 volts, instead of 15 to 20 volts as indicated by the coaxial cylinder method.

[1] Henderson, Abbott, Dahlstrom, Phys. Rev. **41**, 261 (1932).

23. Influence of the Temperature on the Plasticity of Crystals. POL E. DUWEZ, *California Institute of Technology.*—The theory of the plasticity of crystals recently published[1] has been extended in order to take into account the influence of the temperature on the stress strain curve. The model of the deformed crystal, deduced from Zwicky's Secondary Structure theory, shows that the two quantities G and τ_{max}, i.e., the modulus of elasticity and the stress producing rupture of the crystal, are dependent upon the temperature. Furthermore G and τ_{max} vary independently. Therefore the relation between stress and strain remains the same, with G and τ_{max} functions of T instead of constants. The variation of G is known for a number of metals over a wide range of temperatures. In general a linear function can be used, except in the neighborhood of crystallographic or magnetic transition points. Very few data are available concerning the temperature dependence of τ_{max} for single crystals. Many polycrystalline metals were studied up to the melting point. It seems probable that τ_{max} is a function of the ratio T/T_m, T_m being the melting temperature. The curve $\tau_{max}(T/T_m)$ is characteristic and is almost a straight line, except for values of the ratio T/T_m approaching 0 and 1. Simple theoretical calculations may explain the general form of the function $\tau_{max}(T/T_m)$.

[1] Duwez, Phys. Rev. **47**, 494 (1935).

24. The Local Variation of the Earth's Electric Field. JOSEPH G. BROWN, *Stanford University.*—Following a suggestion by Scrase[1] the mean local diurnal variation of the potential gradient has been obtained for 22 land stations assuming that the unitary variation at land sta-

tions, ΔF_1, is equal to the ocean variation, ΔF_0, times the ratio of the mean gradients, F_1/F_0. The resulting local variations are only slightly different from those obtained previously[2] but presumably they are better approximations. Each local variation has been analyzed into a 24-hour component and a daytime depression as before. The local components at all stations have greater amplitudes than the unitary components. The 24-hour components fall into three groups according to latitude. The mean latitude curves are of two types, narrow maximum and broad maximum. The broad maximum type includes stations which are known to be affected by pollution, the narrow maximum type includes stations relatively free from pollution. The polar curves are of the narrow type and the tropical are a very broad type. It is quite evident that some lower atmosphere factors are the chief cause for the 24-hour component rather than a change in height of the conducting layer as previously inferred. Seasonal changes in the depression component indicate very strongly that it is caused by vertical convection.

[1] Scrase, Met. Office, *Geophys. Mem.* No. 60, 1934.
[2] Brown, Phys. Rev. **47**, 259 (1935).

Saturday Morning at 9 o'clock

Physics Department Auditorium, Physics-Biology Building

25. A Study of the Farnsworth Cold Cathode Oscillator. Merle Starr, *University of California.*—A cold cathode regenerative oscillator similar to that described by P. T. Farnsworth has been constructed to give self-maintained oscillations at a natural frequency near 5×10^7 sec.$^{-1}$ with 40 watts energy. The oscillator consists of a collecting ring and two symmetrically placed silver plates treated with oxygen and caesium in proportions to give high efficiency of secondary emission. In operation the two plates are connected to the negative of a potential source, the ring to the positive, and a uniform magnetic field applied parallel to the axis of the tube to prevent excess electron current to the ring. Measurements on a Lecher wire system show that the natural mode of oscillation is determined by the time required for an electron to travel from one plate to the other under the influence of the electric field due to the applied potential difference and the high frequency alternating potential arising from circuit constants. The energy acquired by an electron from the alternating potential is sufficient to produce several secondaries upon impact with the plate, multiplication increasing in this manner to space-charge limitation. Characteristic curves of electron current from the ring *versus* applied voltage are of a nature to make possible radio- or audiofrequency amplification.

26. The Primary Ionization of High Speed Electrons in Nitrogen. Donald H. Loughridge and Harold K. Skramstad, *University of Washington and the Tumor Institute, Swedish Hospital, Seattle, Washington.*—A large expansion chamber in a magnetic field of about 400 gauss is used to study the tracks of high energy beta-rays produced by bombarding a lead screen inside the chamber by gamma radiation from radon. Two photographs at right angles are taken, and the tracks examined by reprojection onto a screen in their original configuration. Measurements are made of the number of primary ions per centimeter path produced in nitrogen. The results can be expressed approximately by the equation: $I=19/\beta^{-1.15\pm.15}$. Measurements on a few tracks in oxygen agree within experimental error with the results of Williams and Terroux. The primary ionization of the positive electrons observed is indistinguishable from that of the negative electrons. Comparisons are made with the theoretical calculations of Bethe, Moller and Bloch, and the agreement is excellent over the range of velocities used. The magnitude obtained for the primary ionization corresponds to an average ionization potential of 16.6 for the 5 outer electrons in the nitrogen atom, which is very near its minimum ionization potential. The variation with velocity checks well for values of $\beta<0.97$ but the predicted increase for very high energies is not observed. Further work with neon and argon is now in progress.

27. The Photometry of Electric Furnace Absorption Multiplets. Robert B. King and Arthur S. King, *Mount Wilson Observatory.*—The intensities of lines in multiplets of iron of temperature classes I and II between λ3650A and λ5500A have been measured in absorption spectra produced in the electric vacuum furnace. The relative intensities have been measured in that part of the "curve of growth" of an absorption line dominated by Döppler broadening, where the total absorption $\sim N\cdot f$. The equivalent breadth of lines in this part of the curve is less than 0.03A at furnace temperatures (about 2100°C) but with high contrast plates measures can be made on lines whose total absorption is less than 0.002A. By keeping the temperature constant and gradually increasing N, lines of the same multiplet and of different multiplets can be passed successively through this part of the curve and measures of their relative intensities made at various stages. Since the atoms are in thermal equilibrium the Boltzmann factor can be applied and the intensities compared with theoretical intensities. The whole "curve of growth" of an absorption line, from the region of Döppler broadening where $I\sim N\cdot f$ to the region of dominance of radiation damping where $I\sim(N\cdot f)^{\frac{1}{2}}$, can be traced. However, under present conditions the latter part of the curve may be influenced considerably by collision broadening.

28. A High Voltage Lenard Tube and Search for Radioactivity Induced by Electron Bombardment. J. J. LIVINGOOD AND A. H. SNELL, *University of California.*—A Sloan type resonance transformer high voltage generator has been adapted to accelerate electrons out into the room by mounting a filament on the high voltage end of the coil, which hangs from its grounded upper end inside a steel vacuum tank. One of the filament current leads is the copper coil itself, the other being the internal concentric copper water-cooling pipe. Electrons are accelerated during alternate half cycles (6 megacycles) towards the grounded tank wall and emerge through a 0.001 inch copper window supported on a water-cooled copper grid. Space charge in the shield around the filament reduces the emission during the lower parts of the voltage waves. Absorption measurements indicate a maximum range of 0.048 inch of aluminum, corresponding to about 845 kilovolts. Fifty-one elements, including deuterium, lead and thorium, have been bombarded for several minutes each with 100 microamperes total current and examined with a Geiger counter for induced radioactivity. No counts above background were obtained, indicating that (a) the range of the radiation is less than 4 cm of air, or that the periods are either (b) a small fraction of a second or else (c) many hours, or (d) that the effect does not exist at the potential used.

29. Solved Example Illustrating a New Property of Least Squares. W. EDWARDS DEMING, *U. S. Bureau of Chemistry and Soils, Washington, D. C.*—In the February 1935 Philosophical Magazine it was shown that when a curve has been fitted by least squares, there is no correlation between the errors of the calculated points and the residuals in the observed points. In the case of a single sample this reduces to the independence of the mean and standard deviation, found by Student in 1908. Mathematically, the general property is expressed by the vanishing of $\Sigma(w_x U_x V_x + w_y U_y V_y)$, the summation to be taken over all points. w_x and V_x denote the weight and residual of the x coordinate of an observed point; U_x denotes the error of the calculated coordinate. w_y, V_y and U_y are similarly defined. The vanishing of this cross-product term is essential for the existence of a chi-square distribution; hence if either the chi-test or the analysis of variance (comparison of *internal* with *external* consistency, as Birge has called it) is to be used for testing the fit of an empirical formula it is necessary to do the fitting by least squares. As an illustration twelve points are fitted with a second degree curve and a numerical evaluation of the cross-product term made. The twelve points were obtained by taking observations with Tippett's *Random Sampling Numbers* on the x and y coordinates of twelve points known to lie on a curve of the form fitted.

30. The Dark Current from Barrier-Layer Photo-Cells. PAUL R. GLEASON, *Colgate University.*—The spontaneous current delivered by barrier-layer photo-cells from several manufacturers has been further investigated[1] when the cells are in complete darkness. This current persists under all conditions under which the cells have been placed, seems to diminish over long periods of time and otherwise appears to be a function only of the temperature. By placing a photronic cell without its glass window in an air tight chamber whose humidity could be varied, it was established that the dark currents are independent of the humidity over the normal range of humidities experienced in laboratory conditions down to zero percent relative humidity attained by desiccating for a period of two weeks. However, in an atmosphere approaching saturation, a much larger current appears, probably due to excessive absorption of moisture by the selenium. The dark current is in the same direction as the self-generated current produced by exposure to light. It varies from cell to cell approximately within the range from 10^{-10} amp. to 10^{-9} amp. Within a group of four Weston Photronic cells, the variation in the dark current bears no relation to their sensitivities for visible light, but seems to be roughly proportional to their sensitivities for x-rays.

[1] Gleason, J. O. S. A. **23**, 193A (1933).

31. Electron Optics of a 3000 kv X-Ray Tube. D. L. WEBSTER, W. W. HANSEN AND P. KIRKPATRICK, *Stanford University.*—The design of an x-ray tube to be operated at potentials up to 3000 kv involves special problems in electron control. Electrical and mechanical considerations necessitate electron paths about 50 feet long from cathode to target, with five intermediate accelerating electrodes. Each electrode unavoidably constitutes a converging electron lens. Students of electron optics have heretofore shown little interest in electrons energetic enough to show relativity effects. It is found that the focal length of an electron lens for fast electrons is less than that for slow electrons in the ratio $\frac{1}{4}((\epsilon+2)/(\epsilon+1))^2$ where ϵ = electron kinetic energy/m_0c^2. An expression for the focal length of an electrostatic electron lens consisting of two coaxial cylindrical electrodes is given which does not involve the usual laborious step by step computation of electron paths. In the present problem all practicable accelerating electrodes are undesirably powerful as lenses, and it is theoretically impossible to image the cathode upon the target without at least one intermediate focus.

32. Absorption of Electrons. SETH H. NEDDERMEYER AND CARL D. ANDERSON, *California Institute of Technology.*—From a new set of about 10,000 of counter-tripped cosmic-ray photographs it was possible to make 166 direct measurements of the energy lost in a 0.35 cm Pb plate by electrons (+ and −) with energies in the range below 150 mev. Among these 166 cases there were 46 in which the particle was apparently stopped by the Pb. A division of these electrons into three groups according to initial energy, *viz.* (1) below 50 mev, (2) 50 to 100, (3) 100 to 150, has given the result that groups 1, 2, 3 with mean initial energies of 28, 71 and 124 mev showed mean specific energy losses of 51, 91 and 90 mev/cm, respectively. A comparison between these values and those obtained theoretically by Bethe and Heitler (in the limiting case of a very thin

plate), *viz.* 62, 140, 250 mev/cm for electrons with energies equal to the above mean initial energies, shows approximate agreement with theory in the low energy range, but indicates a breakdown above 100 mev. The 166 electrons ejected 3 single (+) secondaries and 2 (+ −) pairs, with a mean energy (calling (+'s) pairs) of 10 mev. The observed number and energies of the positron-negatron pairs ejected and the observed losses of energy by the same group of electrons are roughly consistent with the assumption that the pairs arise from the absorption of photons given off in radiative collisions.

33. A Search for Temperature Changes Accompanying Field Current Emission. JOSEPH E. HENDERSON AND G. M. FLEMING, *University of Washington.*—Two platinum-gold thermocouples, one of which was sharpened at the junction to a fine point, the other being blunt, were mounted similarly and close together opposite the anode of a G.E. XP-DFW water-cooled x-ray tube. These thermocouples were mounted in opposition to each other so that any electromotive force generated in both because of general temperature changes would cancel. During the application of the field only the sharp point emitted electrons so that any temperature effect which might accompany the emission would be indicated by a galvanometer connected in series with the two thermocouples. It was possible to detect a difference in temperature of the junctions of less than one degree centigrade. With emission currents ranging up to a few milliamperes, no change in temperature, either cooling or heating, was detected within the limits of experimental error.

34. The Dynamical Theory of Gratings. R. M. LANGER, *California Institute of Technology.* The original work of Wood on intensity anomalies of reflection gratings led Rayleigh to develop a theory which did not use the assumptions of ordinary diffraction theory. Rayleigh's theory explained very little of Wood's observations and much less of the more extended experiments recently made by Strong. Voigt has shown how it is possible to generalize Rayleigh's methods to take into account the finite number of diffracted orders and the finite conductivity of the grating surface. This theory breaks down just in the case where the intensity anomalies become important. Nevertheless it is possible to discuss qualitatively many of the phenomena observed by Strong and unexplained in Rayleigh's theory. These include the occurrence of dark as well as bright bands in various orders when a higher order almost satisfies the condition that its direction is parallel to the surface. The effects of groove form and conductivity of the metal surface are fairly clear and it turns out that only gratings with scratches narrow compared with the grating spacing should give pronounced bands. This situation was recognized by Strong from his experiments and he calls attention to the fact that gratings ruled for spectroscopic work in the visible do not often have these defects because this condition leads to weak diffracted beams. In the infrared the rulings are more often relatively fine and Ingersol has published observations on this effect. Another type of experiment where these anomalies may play a significant part is in the case of x-ray reflections from ruled surfaces. The rulings are light and few and incidence and emergence are almost grazing.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

35. Density and Surface Tension by the Capillary Elevation Method. L. E. DODD, *University of California at Los Angeles.*—Measurement of surface tension by the capillary elevation method requires that the density be known. To avoid temperature difficulties in weighing, one may take a series of readings, on the same test sample, of capillary elevations under a relatively large range of gas pressures, thus obtaining a straight-line graph. The constants of this permit computation of both density and surface tension. By this method measurements have been made on different test liquids, such as methyl alcohol, ethyl alcohol and acetone, with 8 or 10 points graphed in each case. The capillary bore is of the order of 0.2 mm diam. Correlation coefficients indicate linearity of the graph to within about 0.01 percent. The assembled apparatus including manometer is immersed in the same water bath. A non-electric thermostat has been found satisfactory, being adjustable within an ample temperature range.